

Synthesis of CMMAP's Contribution to MJO Research

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In the Mid 2000's, the State of MJO Theory Was a Bit of a Mess

- Review articles by Wang (2005); Zhang (2005) highlighted the following hypotheses for MJO dynamics (some with prejudice):

Wave-CISK

WISHE

Frictional Convergence

Air-sea interaction

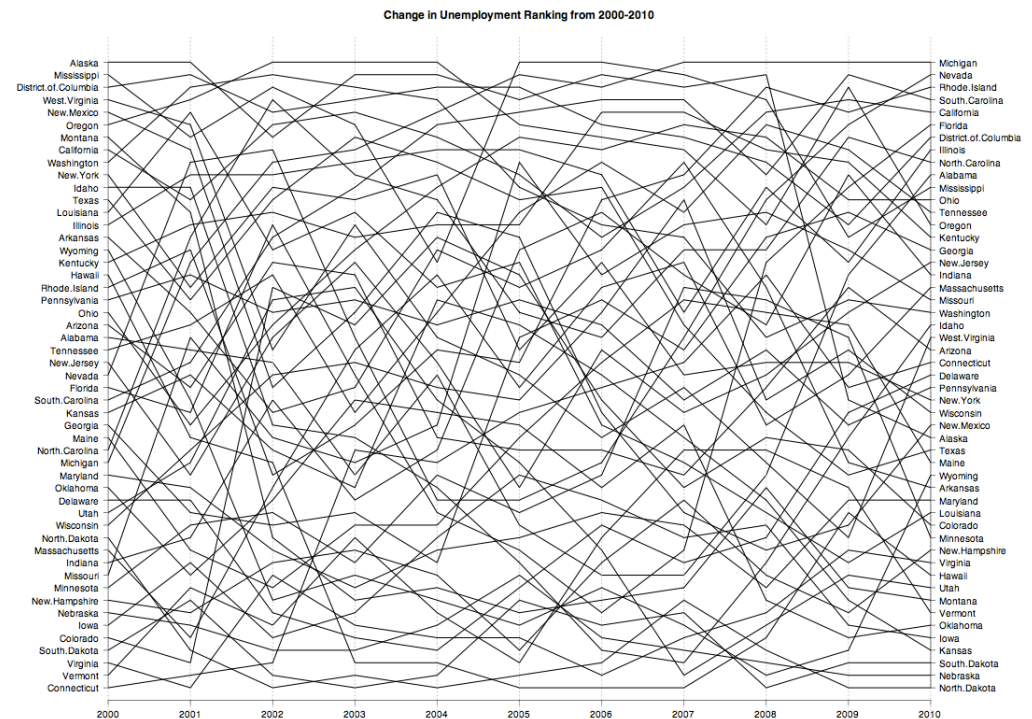
Midlatitude-tropical interactions

Tropical stochastic forcing

Scale-interactions

Cloud-radiation feedbacks

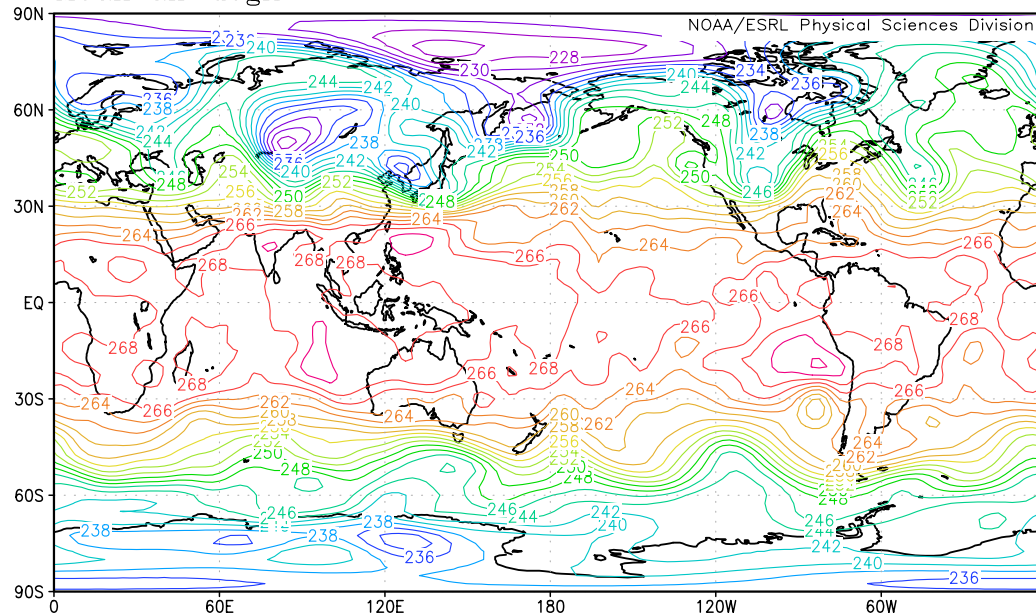
Recharge-discharge and moisture



A Weak Temperature Gradient (WTG) Renaissance

- Building on the work of Charney (1963; 1969) and others

lon: plotted from 0.00 to 357.50
 lat: plotted from -90 to 90.00
 lev: 500.00
 t: Jan 1 2011
 Mean air degK



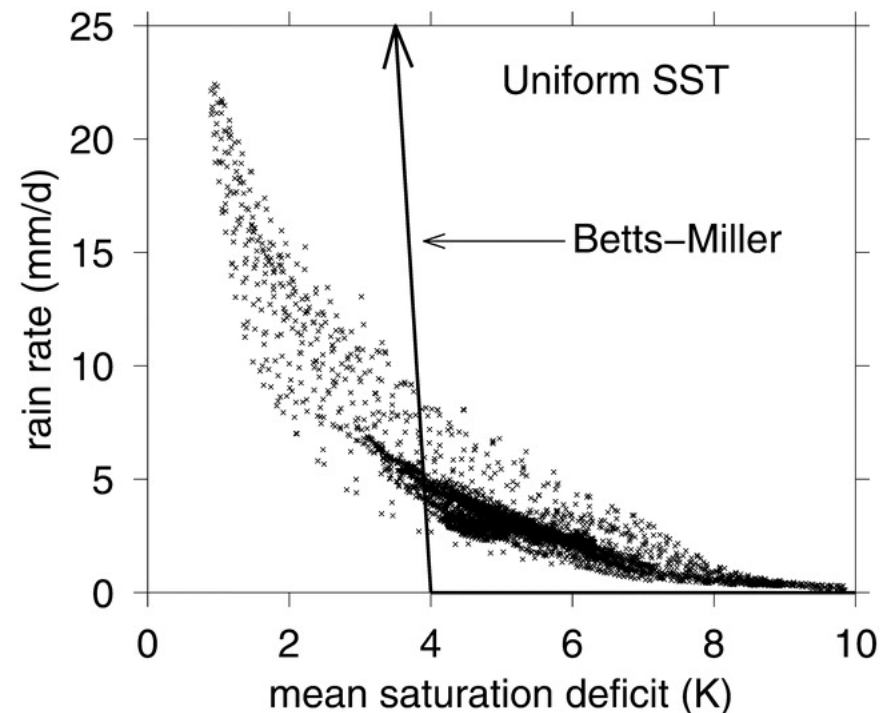
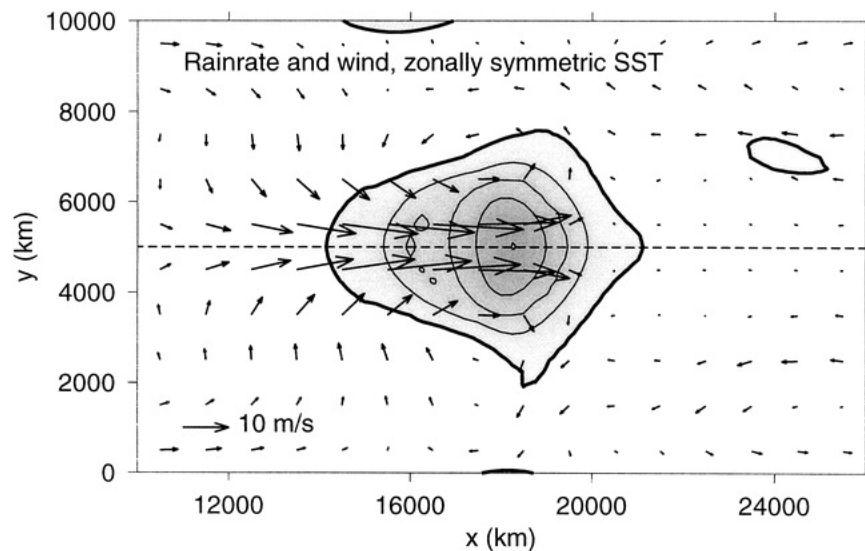
MNCEP Reanalysis Daily Averages Pressure Level GrADS image
 MIN=225.17

$$\omega \sim \left(\frac{\partial s}{\partial p} \right)^{-1} Q_1$$

- An early 2000s renaissance occurred in application of weak temperature gradient (WTG) theory to the tropical atmosphere
Sobel and Bretherton (2000); Raymond (2000); Raymond (2001); Majda and Klein (2003); Bretherton and Sobel (2003); Maloney and Sobel (2004); and many others

Application of WTG to the MJO

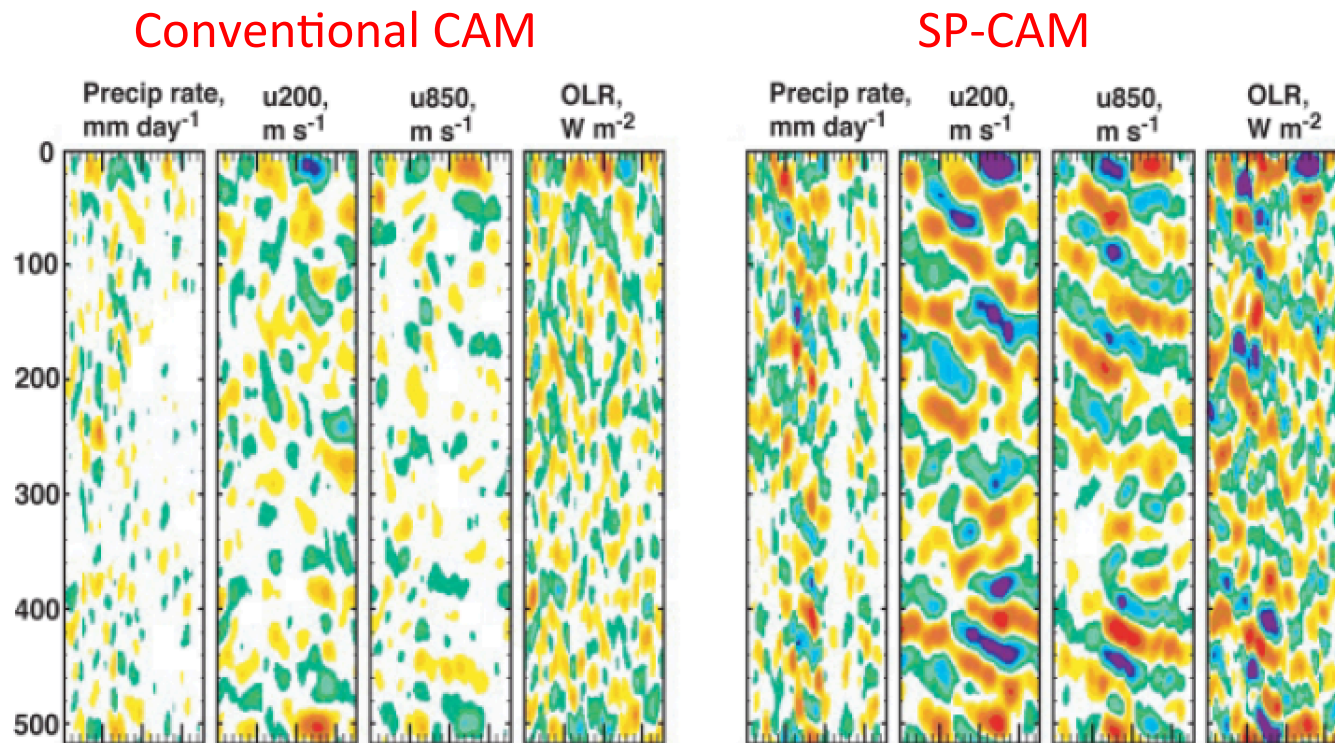
- Raymond (2001) proposed an MJO theory based on WTG thinking



- Propagation and maintenance of the moisture field, and tight coupling of moisture and convection, essential to understanding dynamics of MJO. i.e. ***“moisture mode”***

The Advent of the SP-CAM

- Superparameterized model with arguably world's premier MJO simulation that exhibits many characteristics consistent with new theoretical frameworks for understanding the tropics. ***Don't forget NICAM either***
 - *Convection realistically sensitive to free tropospheric humidity*
 - *Realistic simulation of processes that control tropospheric humidity*



Randall et al. (2003)

see also: Grabowski and Moncrieff (2004); Miura et al. (2007)

In Mid-2000's, Stars Aligned to Make Progress on the MJO

Improved theoretical framework for understanding the tropics

Superparameterization (and NICAM) and brainpower of CMMAP



MJO Nirvana

In Mid-2000's, Stars Aligned to Make Progress on the MJO

Improved theoretical framework for understanding the tropics

Superparameterization (and NICAM) and brainpower of CMMAP



Contributors to CMMAP MJO Research

Dave Randall

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Bill Collins

BN Goswami

Mitch Moncrieff

Wojciech Grabowski

Duane Waliser

P. Mukhopadhyay

Brian Mapes

George Kiladis

Tina Laboy

Heather Morgan

Ariana Gonzales

Kuan-Man Xu

And others.....

Understanding MJO Destabilization and Propagation

CMMAP research and work with CMMAP models has helped forged a consensus on:

The key role of moisture variability in regulating MJO dynamics:

Benedict and Randall (2007; 2009); Hannah and Maloney (2011); Randall (2013); Thayer-Calder and Randall (2009); Zhu et al. (2009); and many others.

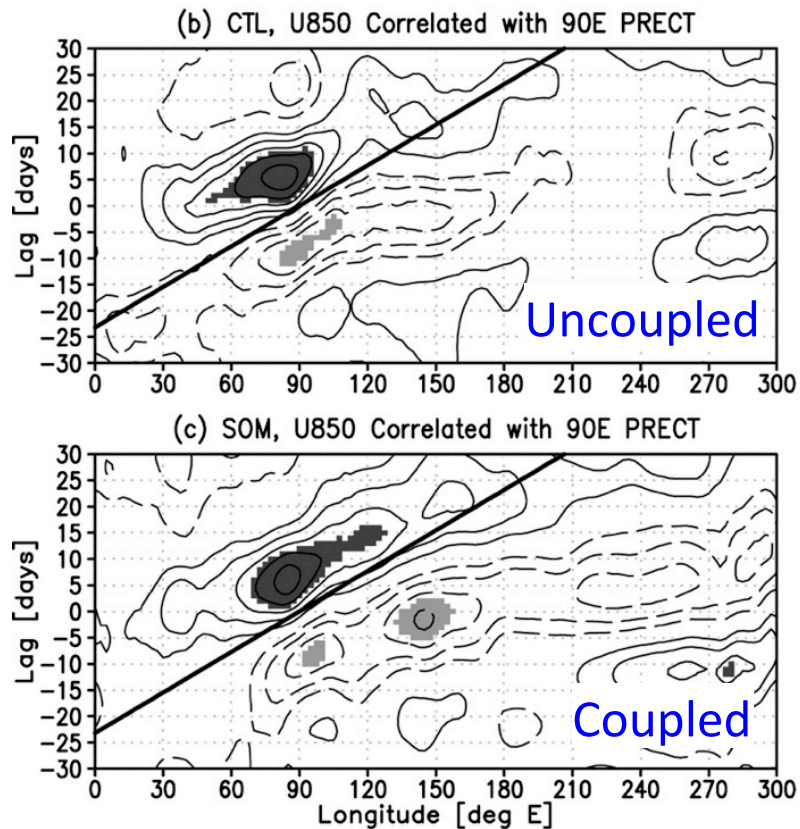
Destabilization of the MJO by radiative feedbacks onto moisture

Andersen and Kuang (2012); Arnold et al. (2013; 2015); Arnold and Randall (2015); Chikira (2014); Hannah and Maloney (2014); Kiranmayi and Maloney (2011a,b); Wolding and Maloney (2015);

The role of horizontal moisture advection in MJO propagation:

Andersen and Kuang (2012); Benedict and Randall (2007); Chikira (2014); Maloney (2009); Maloney et al. (2010); Pritchard and Bretherton (2014);

A Role for Ocean Coupling in MJO Dynamics



CMMAP work with Sp-CAM/CCSM has demonstrated rather conclusively that ocean coupling produces more realistic MJO simulations.

Benedict et al. (2011); DeMott et al. (2014); Stan et al. (2010)

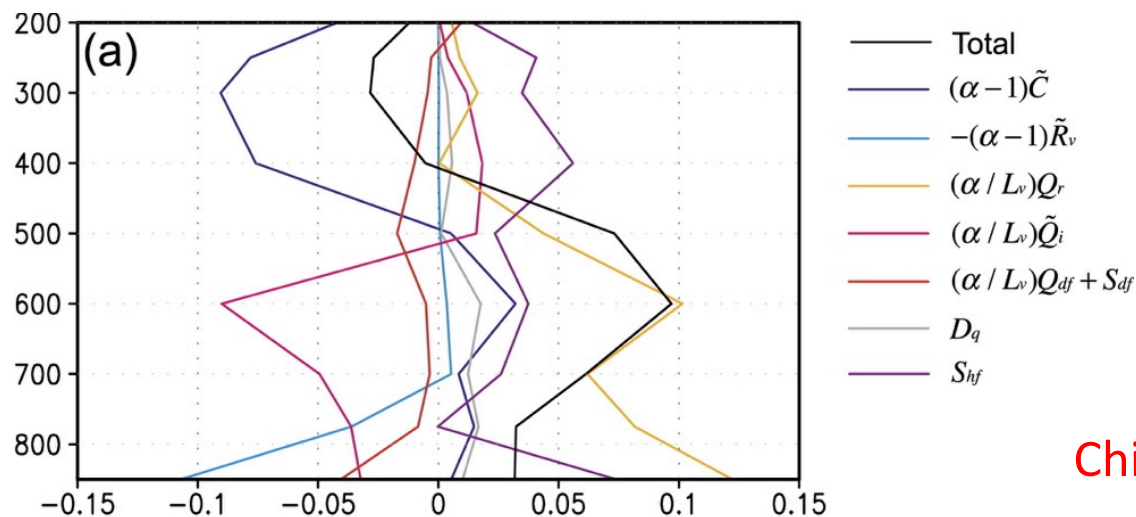
Benedict and Randall (2011)

New Diagnostic Frameworks to Assess MJO Dynamics and the Fidelity of Model Processes

Hierarchy of MJO and mean diagnostics based on the moist static energy and moisture budgets that use WTG theory:

Benedict et al. (2014); Chikira (2014); DeMott et al. (2015); Hannah and Maloney (2011; 2013); Kim et al. (2014); Maloney (2009); Maloney et al. (2014); Riley Dellaripa and Maloney (2015); Wolding and Maloney (2015a,b); Zhang et al. (2013), and others....

Moistening Processes under WTG at Peak MJO Convection



Chikira (2014)

Other CMMAP MJO-Related Accomplishments

The MJO in a Warming Climate

Arnold et al (2013; 2014; 2015); Maloney and Xie (2013)

Multiscale interactions and the MJO

Moncrieff et al. (2010); Moncrieff et al. (2012); Miyakawa et al. (2012)

Collaborations with international community through task forces and working groups (YOTC, WGNE MJO Task Force, NOAA MAPP CMIP5 Task Force, S2S)

Moncrieff et al. (2012); Waliser et al. (2012); Wheeler and Maloney (2013); Sheffield et al. (2013a,b); Maloney et al. (2014)

Boreal summer intraseasonal variability

DeMott et al. (2011; 2013); Goswami et al. (2011; 2013); Krishnamurthy et al. (2014)

Unanswered Questions for Future Work

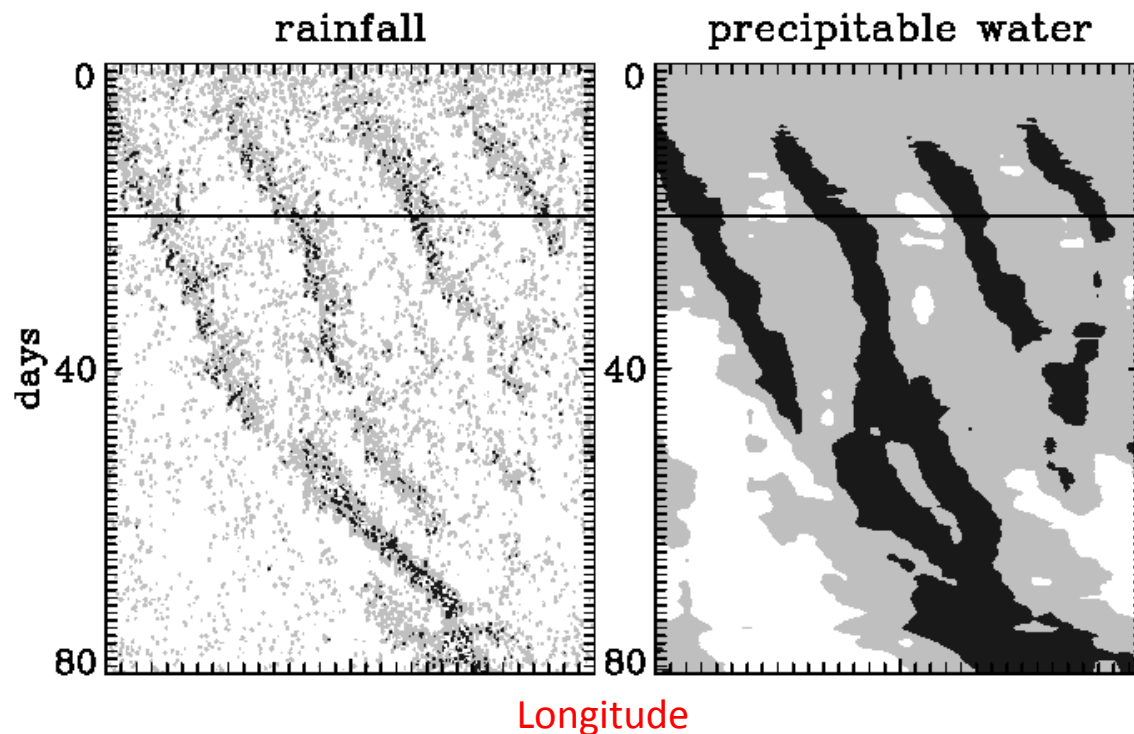
- **Scale selection mechanism for the MJO**
- **Are surface enthalpy feedbacks of first order importance to the MJO, or a second order term?**
- **How does air-sea interaction improve the MJO representation in models?**
- **Why does MJO behavior change in the Maritime Continent?**
- **How can we best translate what we have learned about the MJO within CMMAP to a broader set of models? *Diagnosis and parameterization***



Thanks!

Grabowski and Moncrieff (2004)

- Superparameterized model that was associated with MJO-like variability exhibiting pronounced moisture-convection feedbacks and an important role for radiative feedbacks on moisture



- Foreshadowed subsequent progress in CMMAP on understanding MJO dynamics